State of California
The Resources Agency
Department of Water Resources

CONTAMINANT ACCUMULATION IN FISH, SEDIMENTS, AND THE AQUATIC FOOD CHAIN
-
STUDY PLAN W2, PHASE 2 REPORT

Oroville Facilities Relicensing
FERC Project No. 2100

JUNE 2005

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FERC Project No. 2100

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REPORT SUMMARY

Significant historic and current gold mining, hydropower generation, and industrial activities in the Feather River watershed could contribute metal and organic contaminants to project waters and linked aquatic systems. Sediments laden with metals and organic contaminants could undergo biochemical conversion in the reservoirs, become available to biota, and subsequently bioaccumulate in the food web within project waters. A variety of wildlife, including threatened and endangered species prey on fish from project waters, which also receive significant activity from sport fishermen. This study was undertaken to determine the significance of contamination in fish, crayfish, and sediments in project waters, and evaluate the effect to prey species and humans. The study was divided into two phases; Phase 1 evaluated contaminants in biota within the project area, while Phase 2 evaluates sources of upstream and downstream contaminants including sediments. Phase 2 of the study was also designed to provide additional information within the project area. This report presents the results of Phase 2 of the study.

Organic and metal contaminants in all fish analyzed in Phase 1 exceeded various guidelines and criteria developed to evaluate the significance of contamination and protect wildlife or humans that may consume contaminated fish. Results from Phase 2 provides additional fish tissue analyses to evaluate contamination in reservoir tributaries, additional fish species or areas within project waters, and the Feather River downstream from the project area. Fish tissue analysis from Phase 2 confirms the presence of mercury consistently exceeding USEPA guidelines of 0.3 parts per million (ppm) in most fish species and locations sampled. Salmonids obtained from the Oroville Fish Hatchery were an exception where mercury in fish tissue composites were at relatively low concentrations (less than 0.1 ppm) which do not exceed any current criteria. Polynuclear aromatic hydrocarbons (PAHs) were detected in fish tissue composites obtained from the Oroville Fish Hatchery and Annex. PAHs detected in fish tissue composites include Napthalenes (-C2 and -C3).

Sediments were collected during Phase 1 at 13 sampling locations, subsequently, contaminant analysis was conducted during Phase 2. Results verify the presence of methylmercury widespread over the majority sampling locations with a range of maximum concentration of .029 ng/g to 0.403 ng/g in Lake Oroville, <.019 to .097 in the Forebay and Afterbay, and .245 ng/g at a single Feather River location upstream of the Afterbay Outlet. Total organic carbon (TOC) concentrations ranged from 0.04 to1.60% between sampling locations. Organic carbon concentrations are relative to biomass and may influence the rate of mercury biotransformation.

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1.0 INTRODUCTION

The Environmental Work Group identified contaminant accumulation in fish, sediment, and the aquatic food chain as an issue of concern. Contamination of fish from mercury and other metals and organic contaminants is a significant issue in many areas of California, including the Feather River watershed.

The lands and waters inundated by Lake Oroville and the Thermalito Diversion Pool, as well as the Lake Oroville tributaries, experienced a massive amount of gold mining activity during the Gold Rush era. In addition, small-scale commercial and recreational gold mining activities presently continue in the upper Feather River watershed. Numerous large mercury mines were developed in the Coast Range to supply mercury as an amalgam for gold extraction in the Feather River and other areas. Mercury lost during gold mining operations is slowly being transported downstream with sediments. Though the Gold Rush era has long since passed, significant quantities of mercury still remain on the bottom of Lake Oroville and the Thermalito Diversion Pool and in the tributary streams.

Potentially occurring anoxic conditions beneath the sediment-water interface at the bottom of project reservoirs create ideal conditions for biologically mediated liberation of methylmercury by sulfate-reducing bacteria. The redistribution of methylmercury in the water column during lake mixing in the fall and winter may facilitate bioaccumulation into the food web, including plankton, fish, and piscivorous birds and other animals, including humans.

In addition, other industrial activities in the upper Feather River watershed have contributed metal and organic contaminants, including poly aromatic hydrocarbons (PAH), which also have an affinity for sediments and bioaccumulate in the food web. Re-suspended sediments and recycled metals and organic contaminants in Lake Oroville can be transported downstream to other project waters, including the Thermalito Forebay and Afterbay, Oroville Wildlife Area ponds, and Feather River, where uptake and bioaccumulation in aquatic organisms can occur.

Sediments trapped behind the dam are potentially laden with metals and organic contaminants, which may bioaccumulate in the food web. Sediments carried into Lake Oroville initially deposit into the upper tributary arms. Deposits are transported further into the reservoir due to natural high flow hydrologic events, reduced reservoir levels, and periodic discharge surges from upstream hydropower generation.

1.1 BACKGROUND INFORMATION

Sediments in Feather River tributaries are known to carry metal and organic contaminants. Prior to construction of Oroville Dam, sediments carried by the tributaries and the main stem of the Feather River in the reservoir footprint were transported downstream. Subsequent to completion of the dam, sediments carried by the tributaries settle into the upper arms of Lake Oroville, but are reworked by stream flows as reservoir levels drop throughout the summer and are re-deposited further into the reservoir area. Thermal stratification in the reservoir during the summer can facilitate leaching of metals and organic contaminants from the sediments into the water column, where they become available for uptake by aquatic life or release downstream. In addition, sediment dwelling organisms (e.g., crayfish, insects) ingest the sediments and can absorb contaminants. Contaminants in lower trophic levels are bioaccumulated in higher trophic level organisms, and may reach levels that are deleterious to other organisms (including listed species and humans) that ingest them.

Impoundment of the reservoir created conditions in which sediments possibly laden with contaminants are trapped, which could then allow bioaccumulation of contaminants in the food web. Water with bio-available forms of metals and organic contaminants that is released from the reservoir may contribute to bioaccumulation in downstream organisms. In studies of mercury bioavailability in the Yuba River system, effects of foothill reservoirs on downstream mercury transport were investigated (SFEI, 1996). It was found that significant amounts of mercury contaminated sediments present in the upper Yuba watershed is being transported down into Englebright Reservoir, where the sediment is largely trapped. Aquatic biota below Englebright Dam consistently demonstrated significantly reduced mercury levels, as compared with waters above the reservoir although the USGS observed high mercury loads below the reservoir during the winter of 1995-96. However, USGS believe this mercury was eroded from pre-dam deposits during high flows released from the reservoir. The assumption is that mercury cycling in other Sierra watersheds, including the Feather River system, is similar to that found in the Yuba. Therefore, much but clearly not all, of the mercury remaining from historic gold mining may be unavailable for downstream transport and biomagnification in the Bay-Delta estuary. In the few high mercury rivers without dams, particularly the Consumnes, direct transport of historic gold mining mercury into the Delta remains unimpeded. Thus, bioaccumulation may not have been significant in the Feather River downstream from Oroville dam prior to its construction because the metals and organic contaminants were bound to the sediment particles, not readily available for uptake, and transported out of the Project area to the Delta with higher flows.

A variety of wildlife species prey on fish or other aquatic organisms from project waters. These wildlife species could suffer adverse physiological or reproductive responses from ingestion of prey species containing elevated levels of certain contaminants. Contaminants ingested by wildlife species that prey on aquatic species from project waters can also be bioaccumulated and passed on to other predatory fish and wildlife species that in turn prey on them.

In addition, some contaminants are not strong bioaccumulators (e.g., some metals such as copper and arsenic), but may be mobilized and made available to the biota under certain environmental conditions (e.g., re-suspension of sediment deposits from the arms to the main body, depressed oxygen and pH conditions, etc.) found in the reservoir. Organisms can become re-exposed to contaminants as the lake level drops and deposited sediments are re-suspended and transported further into the reservoir. The shallow, organic rich waters of the Thermalito Forebay and Afterbay could contribute to the methylation of mercury and dissolution of other metals and organic contaminants. Environmental conditions such as these in project water bodies may promote mobilization of sediment bound contaminants and transport out of the "project area" where they could affect threatened and endangered species.

1.1.1 Statutory/Regulatory Requirements

Demonstration of compliance with basin plan objectives is necessary for the SWRCB to issue a water quality certification. Basin plan objectives include provisions against increases in suspended sediment discharges, deposition of material that adversely affect beneficial uses, and toxic substances that produce detrimental effects to humans, plants, animals, and aquatic life. The water quality certification is needed for license renewal with the Federal Energy Regulatory Commission.

1.1.2 Study Area

The study area includes the Oroville reservoir tributaries, the area within FERC project boundary waters, and the Feather River downstream from the project boundary. The first phase of this study focused on evaluation of contaminants in FERC project waters. Phase 2 added areas upstream and downstream of the FERC project boundary waters.

1.1.2.1 Description

Water bodies sampled for Phase 2 of the study included the North Fork, Middle Fork, South Fork, and West Branch of the Feather River. Additional stations were also sampled on Lake Oroville along with downstream stations including the Thermalito Afterbay, Two ponds in the Oroville Wildlife area, and the Feather River near Gridley.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project, a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area, Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts. The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the Oroville Wildlife Area.

The Oroville Wildlife Area comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. DFG’s habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

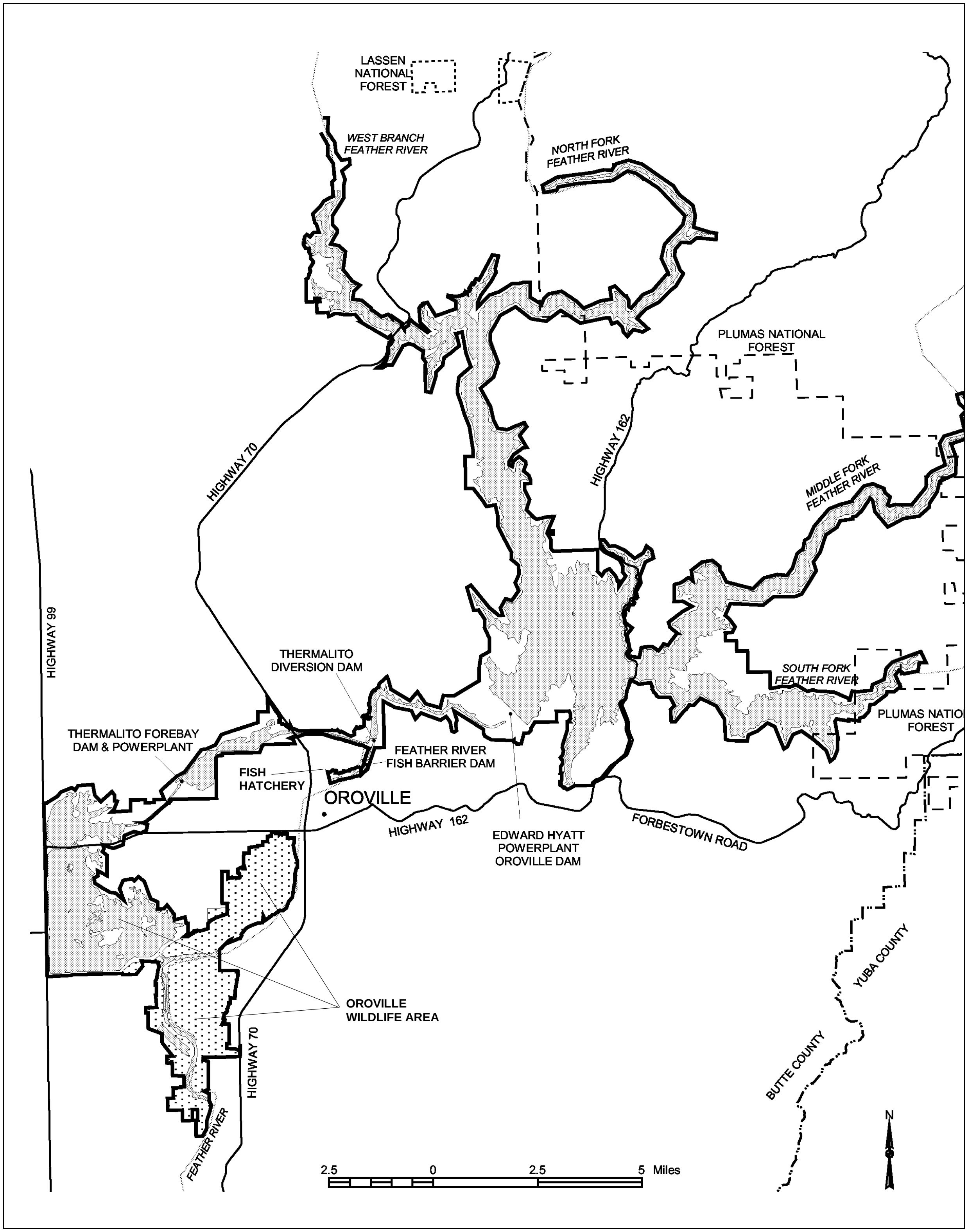


Figure 1.2-1. Oroville Facilities FERC Project Boundary

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning are conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet; however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water can be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and the California Department of Fish and Game entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52 ºF for September, 51 ºF for October and November, 55 ºF for December through March, 51 ºF for April through May 15, 55 ºF for last half of May, 56 ºF for June 1-15, 60 ºF for June 16 through August 15, and 58 ºF for August 16-31. A temperature range of plus or minus 4 ºF is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warm water fish.

The National Oceanic and Atmospheric Administration Fisheries have also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65 ºF on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65 ºF from approximately April through mid May, and 59 ºF during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) acre feet (af) are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 million acre feet (maf). After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from the Department of Water Resources water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers. Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

Information derived from this study will be used to demonstrate compliance with water quality standards and other appropriate requirements in the application for water quality certification. Information from the study is also needed to address DFG, U.S. Forest Service, U.S. Fish and Wildlife Service, and NOAA Fisheries concerns related to fish and wildlife species that feed on potentially contaminated aquatic organisms in the project area.

Analyses of fish tissue for mercury and organic contaminants are necessary to determine project effects and compliance with Basin Plan objectives. Since recreation, including fishing, is a major beneficial use at project facilities, analysis of fish tissues provides valuable information for fish consumption advisories.

Sediment analysis will help determine whether contamination of biota is attributable to contaminant sources located within the reservoir or upstream from the project area, and if contamination is local or widespread. Certain areas may be less contaminated than others and not warrant the same restrictions as other reservoir locations for consumption of fish. Identification of the location and extent of sediment contamination will be used to develop reservoir management practices (licensing conditions) designed to improve the overall water quality and natural and recreational resources of the reservoir. In addition, sediment contamination information will be used to focus efforts to reduce sediment loading for improvement of water quality in the reservoir.

3.0 STUDY OBJECTIVE(S)

The objectives of the study are to: 1) determine the magnitude and extent of bioaccumulation of metals and organic contaminants in aquatic organisms and sediments associated with the tributaries and effluent waters of the project area and within the project area. 2) identify sources and potential pathways of contamination that contribute to bioaccumulation including contaminated sediments deposited as a result of project features, operations, and maintenance, and 3) provide information that could be used to develop potential protection, mitigation and enhancement measures.

3.1 APPLICATION OF STUDY INFORMATION

Information from the study will be used to determine compliance with basin plan objectives, which is necessary for the SWRCB to issue a water quality certification. The water quality certification is needed for license renewal with the FERC.

In addition, information from the study will be used to evaluate effects to fish and wildlife species that feed on potentially contaminated aquatic organisms in the project area, which is a concern to several agencies, including the CDFG, USFS, USFWS, and NOAA Fisheries.

OEHHA will use information developed from the study to determine whether risks to human health exist due to consumption of contaminated fish from affected waters. OEHHA may request additional studies to more accurately determine human health risks, or may decide to issue a health advisory suggesting that certain demographic groups limit consumption of fish from the affected waters.

The study will also provide information that may be useful in determining sources of contaminants so that the role of the project in contributing to contamination may be ascertained. This may lead to the development of measures to address water quality problems and/or protect public health.

4.0 METHODOLOGY

The study was designed to be conducted in phases. The first phase emphasized analysis of metals and organic contaminants in fish and crayfish in the project area. Phase 1 collected fish tissues for analysis and sediment samples for later analysis. The Environmental Work Group determined that sediments should be analyzed and reported in Phase 2 from all sampling sites based on water quality data from Study Plan SPW1. Sediments from all 13 sampling sites were analyzed for total mercury, methylmercury, and total organic carbon.

Fish collection and analysis from additional sites were included in Phase 2 to supplement mercury fish tissue data from the first phase. Additional fish sampling sites from within the project boundary, upstream, and downstream from the project were included to broaden the scope of the study. Tissue composites from several locations were also analyzed for polynuclear aromatic hydrocarbons as determined by the work group.

4.1 STUDY DESIGN

Water bodies sampled during Phase 2 of the study include: Lake Oroville, Main Fish Hatchery, Hatchery Annex, Thermalito Afterbay, two Oroville Wildlife Area ponds, two tributaries above Lake Oroville and the Feather River near Gridley. Tasks undertaken in Phase 2 included sample collection, laboratory analyses, and data interpretation.

In order to obtain a representative sample of different trophic levels within the aquatic community specific fish species were targeted. Targeted species included trout, bass, coho salmon, catfish, sunfish and carp. The workgroup suggested sampling in the major tributaries of Lake Oroville should consist of trout and bass. The three arms of the main body of Lake Oroville fish samples should consist of coho salmon, bass, catfish, and sunfish. Hatchery raised species should include Coho, Chinook, and Steelhead. Species at the downstream sampling sites such as the Thermalito Afterbay and Oroville Wildlife ponds should consist of bass, carp, and sunfish. However, not all sites contained the originally targeted species, nor could the desired numbers of fish be collected at each site. The Environmental Workgroup Task Force suggested, based on similar trophic activity, that pikeminnow could be substituted for the bass species, and carp could be substituted for the catfish.

Fish were collected throughout 2003 with electroshockers, gill nets, hooks and lines, and seines. Fish were weighed and measured, wrapped in aluminum foil, and immediately frozen for transport to the laboratory. A majority of the fish were individually analyzed for total mercury. The remaining samples with additional fish from the Feather River Hatchery were composited according to species. Composites were analyzed for poly aromatic hydrocarbons and methylmercury following the protocol of OEHHA. Each composite was composed of fish with no greater than 25 percent difference in fork length between the largest and smallest individual.

Sediments were analyzed from Lake Oroville locations where Phase 1 fish were collected including, McCabe Cove (upper SF arm), lower SF arm, upper and lower MF arm, NF arm near Bloomer Canyon, NF arm near Foreman Creek, Bidwell Marina arm, and from near the spillway launch ramp. Additional sediment samples were obtained from areas of the north and south Afterbay, north Forebay swim area, Mile Long Pond, and from the Feather River upstream from the Afterbay Outlet. . Sediments were collected with a sediment core sampler in deeper waters, and with a hand corer or teflon spoons in shallower waters following methods of the U. S. Geological Survey (USGS 1994). The top six inches of sediments in ten cores were composited and subsampled into teflon bottles. Sediments collected with teflon spoons from ten areas at shallow monitoring sites were also composited and subsampled into teflon bottles. The bottles were frozen during Phase 1, then analyzed for contaminants during Phase 2 (Dave Crane, DFG Water Pollution Control Laboratory, pers. comm.).

4.1.1 Sampling Sites

Sampling sites for fish were selected from each of the water bodies associated with the Oroville project area, tributaries and downstream waters. Sampling sites were selected to be representative of the particular water body.

4.1.1.1 Lake Oroville

Fish were collected from sampling sites in each of the North, Middle, and South Fork arms and from both the east (Bidwell Marina arm) and west (Spillway arm) sides of the main body of the reservoir (Figure 4.1-1). Fish species caught at these sites included large mouth bass, spotted bass, blue gill sunfish, black crappie, channel catfish, coho salmon and carp (Table 4.1-1).

4.1.1.2 Feather River Fish Hatchery and Annex

Fish samples were obtained from the fish hatchery and the hatchery annex. Hatchery raised coho, and hatchery spawned, adult chinook salmon, and steelhead were acquired from the hatchery. Age-0 coho salmon were obtained from the main hatchery complex and the hatchery annex.

4.1.1.3 Thermalito Afterbay

The Thermalito Afterbay was sampled in both the northern and southern regions using electroshocking boats. Largemouth bass, redear sunfish, and carp were obtained from both north and south Afterbay locations. Additionally, channel catfish were obtained from the south Afterbay.

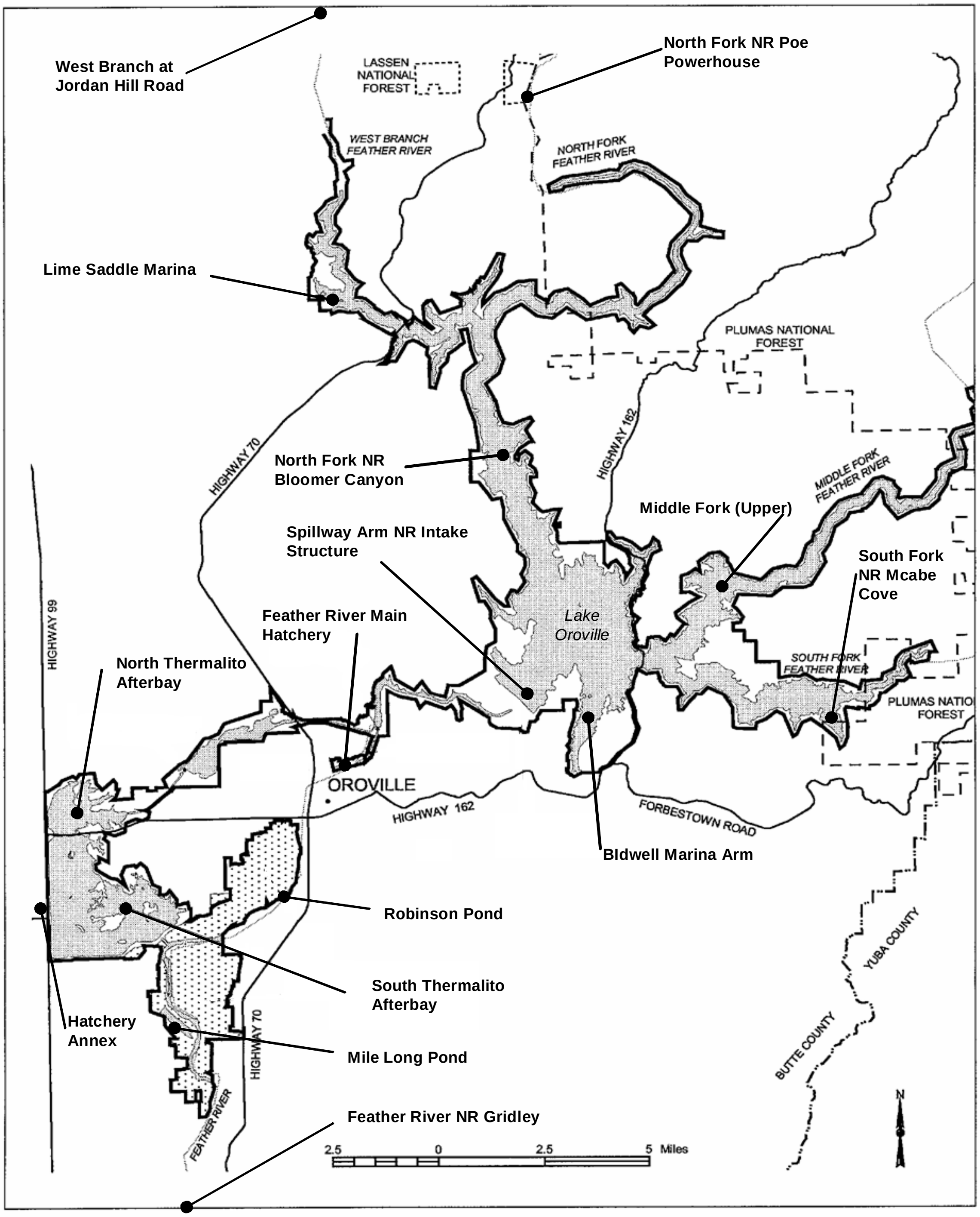


Figure 4.1-1. Fish Sampling Sites

Table 4.1-1. Fish Collected for Contaminant Analyses

Sampling Location	Bass	Minnow	Sunfish	Catfish	Carp	Salmonids
Tributaries						
West Branch						8 RBT
North Fork	1 SPB,9 SMB	5 PM,1 HH				1 RBT,1 BT
Lake Oroville						
Bidwell Marina Arm	7 LMB,6 SPB					1 COHO
Lime Saddle Marina	5 LMB,9 SPB		3 BGS		4	
Spillway Arm						9 COHO
SF Lake Oroville	7 LMB,6 SPB		2 BCR			
MF Lake Oroville	16 SPB		1 BG	3 CHC		
NF Lake Oroville	9 SPB			2 CHC		2 COHO
Downstream						
North Thermalito Afterbay	9 LMB		2 RES		5	
South Thermalito Afterbay	15 LMB		1 RES	5 CHC		
Robinson Pond	8 LMB				2	
Mile Long Pond	5 LMB		10 HY	1 BRB		
Feather River near Gridley	7 LMB	7 PM,7 HH				
Main Hatchery						12 COHO, 8 CHN,7 STH
Hatchery Annex						12 COHO

SPB-Spotted Bass, LMB-Largemouth Bass, SMB-Smallmouth Bass, CHC-Channel Catfish, BRB-Brown Bullhead, RES-Redear Sunfish, PM-Pike Minnow, HH-Hardhead, RBT-Rainbow Trout, BT-Brown Trout, COHO-Coho Salmon, BG-Blue Gill, BGS-Blue Gill Sunfish, HY- Sunfish Hybrid, BCR-Black Crappie, SASU-Sacramento Sucker, CHN- Chinook Salmon, STH- Steelhead

4.1.1.4 Lower Feather River

The Feather River was sampled downstream from the project boundary at locations adjacent to the Gridley boat launch. Largemouth bass, pike minnow, and hardhead were collected from the area.

4.1.1.5 Oroville Wildlife Area

Two representative ponds were sampled in the Oroville Wildlife Area. Warmwater fish species collected from these ponds include largemouth bass, brown bullhead and sunfish hybrids from Mile Long Pond. Largemouth bass and carp were acquired from Robinson Pond.

4.1.2 Laboratory Analyses

Analytical procedures for this study generally followed those used in the Toxic Substances Monitoring Program conducted by the SWRCB and DFG (SWRCB 1996). Total mercury and polynuclear aromatic hydrocarbons were analyzed from fish tissues. Sediments were analyzed for total mercury, methylmercury, total organic carbon, and grain size. (Table 4.1-2).

Table 4.1-2. Metals and Organic Contaminants Analyzed from Fish and Sediments

Analyte	Reporting Limit ppb (ng/g)	Analyte	Reporting Limit ppb (ng/g)
Polynuclear Aromatic Hydrocarbons by EPA Method 8270C/SIM			
acenaphthene	10	fluoranthene	10
acenaphthylene	10	fluorene	10
anthracene	10	indeno(1,2,3-cd) pyrene	10
benzo(a)anthracene	10	3-methylcholanthrene	10
benzo(b, j&k)fluoranthene	10	1-methylnaphthalene	10
benzo(g,h,i)perylene	10	2-methylnaphthalene	10
benzo(a)pyrene	10	1-methylphenanthrene	70
benzo(e)pyrene	10	naphthalene	10
biphenyl	10	perylene	10
chrysene	10	phenanthrene	10
dibenzo(a,h)anthracene	10	pyrene	10
2,6-dimethylnaphthalene	10	2,3,5-trimethylnaphthalene	10
Metals by EPA Method 6020 (ICPMS)			
Methylmercury	0.019	mercury	0.01
selenium*	0.02		
Total Organic Carbon EPA Method 9060 Kahn Method			
Total Organic Carbon	%0.01 Dry Weight		

* analysis with methanol addition

Methylmercury is assumed to be the form of mercury available for bioaccumulation in the food web. Most mercury in fish tissues is in the methylmercury fraction. Total mercury, however, is typically analyzed from fish tissue and is assumed to represent the methylmercury content of tissues. Fish muscle tissue (filet) is typically analyzed for mercury. The laboratory performed these typical analyses, as well as analyses of all the metals from most filet samples. Organic chemicals in the fish were analyzed from composited filets from select locations. All analyses for organic contaminants were performed at the California DFG Water Pollution Control Laboratory in Rancho Cordova, while metals analyses were performed at the DFG Moss Landing Marine Laboratories in Monterey.

Fish obtained from sampling sites were individually analyzed for total mercury contamination except those collected at the main hatchery and the hatchery annex. Main hatchery, annex hatchery, Lake Oroville Spillway Arm, and Thermalito Afterbay samples were composited up to 12 fish following OEHHA guidelines (Margie Gassel, OEHHA, pers. comm.). The composites of age-0 coho collected at the main hatchery and annex were analyzed for polynuclear aromatic hydrocarbons and total mercury. Hatchery and annex samples of spawned steelhead, and spawned chinook were composited and analyzed for total mercury.

Sediment samples from thirteen sites collected during phase 1 were analyzed for total mercury, total methylmercury and total organic carbon. Sediments were thawed and analyzed at the DFG and Moss Landing Marine laboratories.

4.2 DATA INTERPRETATION

Criteria and guidance values for protection of human health and wildlife from contaminant accumulation or ingestion were researched and reviewed for those contaminants identified in the fish from this study. Criteria and guidance values reviewed include numerical criteria and guidance values of the USEPA, OEHHA, SWRCB, U.S. Food and Drug Administration, Food and Agriculture Organization of the United Nations, USFWS, Environment Canada, National Academies of Sciences and Engineering, and New York Department of Environmental Conservation. Unfortunately, few criteria or guidelines have been developed for protection of predatory wildlife species from ingestion of prey containing metal or organic contaminants, though the USFWS and USEPA are beginning efforts to evaluate toxicity data, which may eventually lead to development of protective criteria (Dan Russell, Senior Environmental Contaminant Specialist, USFWS, Sacramento, pers. comm.).

4.2.1 USEPA and OEHHA

The USEPA has recommended screening values for 25 chemical contaminants that have been observed to bioaccumulate in fish tissues (Brodberg and Pollock 1999). The screening value approach is recommended by the USEPA to identify chemical contaminants in fish tissue at concentrations that may be of human health concern for frequent consumers of sport fish. Screening values are not intended to be used for issuance of health advisories, but to identify fish species and contaminants for which more intensive information is needed. The USEPA screening values were calculated for a 70 kg (155 lb.) adult with a fish consumption value of 6.5 g (0.23 oz.) per day. Screening values for use in California lakes were calculated by OEHHA according to USEPA guidance for a 70 kg adult, but using a consumption value of 21 g (0.74 oz.) per day.

As required by Section 304(a) of the Clean Water Act, the USEPA revised the water quality criteria for mercury in 2001 to reflect the latest scientific knowledge on effects to health (USEPA 2001). The USEPA determined that the major pathway for human exposure to methylmercury was through consumption of contaminated fish. Therefore, the USEPA concluded that a fish tissue residue water quality criterion for methylmercury was more appropriate than a water column based water quality criterion. The fish tissue residue criterion for protection of human health was calculated to be 0.3 mg methylmercury/kg of fish.

4.2.2 Toxic Substances Monitoring Program

The SWRCB has conducted the Toxic Substances Monitoring Program since 1976 to provide information on the occurrence of toxic substances in fish and other aquatic life. Results from the TSMP are used by the SWRCB and Regional Water Quality Control Boards in Water Quality Assessment reports to identify impaired waterbodies. The TSMP uses several “criteria” for evaluation of impairment, including the maximum tissue residue level, elevated data level, USFDA action level, NAS guideline, and median international standard.

Maximum tissue residue levels (MTRL) were developed by SWRCB staff from human health water quality objectives in the November 16, 1990 draft Functional Equivalent Document – Development of Water Quality Plans for Inland Surface Waters of California and Enclosed Bays and Estuaries of California, the April 9, 1991 draft Supplement to the Functional Equivalent Document, and the 1997 California Ocean Plan (SWRCB 1996). The MTRLs were calculated by multiplying the draft human health water quality criteria by the bioconcentration factor for each substance, and are an assessment tool for indicating water bodies with potential human health concerns rather than compliance or enforcement criteria. MTRLs are compared only to filet or edible tissue samples and not whole body or liver samples.

Elevated data levels (EDL) are used by the SWRCB to compare results of current studies with results from previous studies. The EDL is calculated by ranking all of the results for a given chemical from the highest to the lowest concentration measured, including those records where the chemical was not detected. A cumulative distribution is constructed and percentile rankings are calculated. The 85th percentile was chosen by the SWRCB as an indication that a chemical is elevated from the median, while the 95th percentile was chosen to indicate values that are highly elevated above the mean. These measures provide a guide to determine if a chemical has been found in unusually high concentrations, and are not directly related to potentially adverse human or animal health effects.

The USFDA has established maximum concentration levels, termed action levels, for some toxic substances in human foods based on assumptions of the quantities of food consumed by humans and upon the frequency of their consumption (SWRCB 1996). The action levels are intended to protect humans from the chronic effects of toxic substances consumed in foodstuffs.

The NAS and NAE have established recommended maximum concentrations of toxic substances in freshwater fish tissues (NAS 1972). These guidelines established water quality recommendations to protect aquatic organisms as well as the predators of the organisms.

Median international standards for metals were developed from a survey by the FAO of health protection criteria used by member nations. These standards do not apply within the United States, but provide an indication of concentrations of metals that other countries have determined to be elevated in fish tissues.

4.2.3 New York Guidelines

The NYDEC developed guidelines for the protection of fish-eating wildlife. The guidelines are based on the laboratory animal toxicology database used to derive criteria for protection of human health, but were extrapolated from laboratory animals to wildlife. From all target species, the bird and mammal with the greatest ratios of daily food consumption to body weight were used to derive the wildlife criteria (Newell et al. 1987). Because several birds consume about 20 percent of their body weight per day, a generic bird, with a body weight of 1 kg (2.2 lbs.) and food consumption of 0.2 kg (7 oz.) per day, was selected. The mink, with an average body weight of 1 kg and food consumption of 0.15 kg (5.3 oz.) per day, was used to represent fish-eating mammals.

4.2.4 Canadian Tissue Residue Guidelines

Canadian tissue residue guidelines were developed by the National Guidelines and Standards Office of Environment Canada to protect wildlife that consume aquatic biota (EC 2000). The guidelines were calculated from the most sensitive of the available toxicity tests and applied to Canadian species with the largest food intake/body weight ratio, and therefore are conservative guidelines.

4.2.5 U.S. Fish and Wildlife Service

The USFWS published a series of Contaminant Hazard Reviews from 1985 to 1998. Each review evaluated hazards to fish, wildlife, and invertebrates for a specific contaminant. The reviews discuss sources and uses, chemical properties, mode of action, background concentrations, lethal and sub-lethal effects where known, and recommendations of contaminant levels in fish to protect birds and wildlife.

The USFWS also evaluated the USEPA human health criterion for mercury to determine the protectiveness for threatened and endangered wildlife in California (USFWS 2003). The USEPA in 2001 developed a recommended water criterion based on a tissue residue concentration of 0.3 mg/kg in edible portions of fish tissue to protect human health. As part of Endangered Species Act consultation for promulgation of this criterion in California, the USEPA agreed that the human health criterion should be sufficient to protect federally listed aquatic and aquatic-dependent wildlife in California. The USFWS conducted a biological evaluation of the effects of the proposed action on federally listed and proposed threatened and endangered species within California. A “wildlife value” was calculated to protect wildlife species that is analogous to the tissue residue concentration for human health protection. A wildlife value was determined for each species of concern using body weight, total daily food ingestion rate, and a protective reference dose.

5.0 STUDY RESULTS

Fish tissue analysis from Phase 2 confirms the presence of mercury consistently exceeding EPA guidelines of 0.3 parts per million (ppm) in most fish species and locations sampled (FIG 5.1.2-1). Salmonids obtained from the Oroville Fish Hatchery were an exception where mercury in fish tissue composites were at relatively low concentrations (less than 0.1 ppm) and do not exceed any current criteria. Polynuclear aromatic hydrocarbons were detected in fish tissue composites obtained from the Oroville Fish Hatchery. Polynuclear aromatic hydrocarbons detected in fish tissue composites include *Napthalenes* (-*C2* and -*C3*). (Table 5.1.1-1).

Sediments were collected during Phase 1 at 13 sampling locations and contaminant analysis was conducted during Phase 2. Results verify that the presence of methylmercury in sediments is widespread over the majority of the sampling locations. However, total mercury concentrations at all sample locations were below reporting limits which indicates mercury methylation is occurring in the sediments. Total organic carbon (TOC) was also detected in all sampling locations, which may increase the rate of mercury biotransformation (Table 5.1-2).

5.1 RELATIONSHIP OF RESULTS TO CRITERIA AND GUIDELINES

Organic compounds and metals detected were compared to the guidelines and criteria to determine whether elevated or harmful levels were present in fish from project area waters.

<u>5.1.1 Organic Contaminants</u>

5.1.1.1 Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic hydrocarbons (PAHs) are derived from a variety of sources, including petroleum products, industrial activities, and combustion processes. Used motor oil is a common source of PAHs which often make their way into aquatic habitats via storm water runoff. The heavier PAHs, such as benzo(a)pyrene, are potent carcinogens, while some of lighter compounds, such as naphthalene are more acutely toxic. Because most PAHs are readily metabolized by fish, they do not tend to bioaccumulate. The EPA Office of Health and Environmental Assessment issued guidance for quantitative risk assessment of PAHs in which an estimated order of potential potency for 14 PAHs relative to benzo(a)pyrene (screening value 0.647 parts per billion), is recommended (EPA 2001). None of these 15 PAHs, including benzo(a)pyrene, were detected above DFG reporting limits (RL) in Project fish.

PAHs were detected in coho composites obtained from the Oroville Fish Hatchery and Hatchery Annex. Detected PAHs in fish tissue composites include *Napthalenes* (-*C2* and -*C3*). Napthalenes were detected at relatively low concentrations from 3.50 to 13.7 parts per billion. Napthalenes are not included with the 15 EPA recommended screening values (SV). All other PAHs analyzed from fish composites, including benzo(a)pyrene, were below reporting limits(Table 5.0-1). However, the DFG Laboratory RLs were over three times higher than the SV for benzo(a)pyrene.

Table 5.1.1-1. PAHs in fish from the Oroville Main and Annex Hatcheries (Dry Weight ppb (ng/g))

Sample Location	**Main Hatchery**	**Hatchery Annex**
PAH	**ng/g (ppb) Dry Weight**	**ng/g (ppb) Dry Weight**
Naphthalene	<RL	<RL
Methylnaphthalene, 2-	<RL	<RL
Methylnaphthalene, 1-	<RL	<RL
Dimethylnaphthalene, 2,6-	<RL	<RL
Trimethylnaphthalene, 2,3,5-	<RL	<RL
Naphthalenes, C1 -	<RL	<RL
Naphthalenes, C2 -	3.90	<RL
Naphthalenes, C3 -	13.7	5.28
Naphthalenes, C4 -	<RL	<RL
Biphenyl	<RL	<RL
Acenaphthylene	<RL	<RL
Acenaphthene	<RL	<RL
Fluorene	<RL	<RL
Methylfluorene, 1-	<RL	<RL
Fluorenes, C1 -	<RL	<RL
Fluorenes, C2 -	<RL	<RL
Fluorenes, C3 -	<RL	<RL
Dibenzothiophene	<RL	<RL
Methyldibenzothiophene, 4-	<RL	<RL
Dibenzothiophenes, C1 -	<RL	<RL
Dibenzothiophenes, C2 -	<RL	<RL
Dibenzothiophenes, C3 -	<RL	<RL
Phenanthrene	<RL	<RL
Methylphenanthrene, 1-	<RL	<RL
Dimethylphenanthrene, 3,6-	<RL	<RL
Phenanthrene/Anthracene, C1 -	<RL	<RL
Phenanthrene/Anthracene, C2 -	<RL	<RL
Phenanthrene/Anthracene, C3 -	<RL	<RL
Phenanthrene/Anthracene, C4 -	<RL	<RL
Anthracene	<RL	<RL
Fluoranthene	<RL	<RL
Methylfluoranthene, 2-	<RL	<RL
Fluoranthene/Pyrenes, C1 -	<RL	<RL
Pyrene	<RL	<RL

Sample Location	Main Hatchery	Hatchery Annex
PAH	**ng/g (ppb) Dry Weight**	**ng/g (ppb) Dry Weight**
Benz(a)anthracene	<RL	<RL
Chrysene	<RL	<RL
Chrysenes, C1 -	<RL	<RL
Chrysenes, C2 -	<RL	<RL
Chrysenes, C3 -	<RL	<RL
Benzo(b)fluoranthene	<RL	<RL
Benzo(k)fluoranthene	<RL	<RL
Benzo(e)pyrene	<RL	<RL
Benzo(a)pyrene	<RL	<RL
Perylene	<RL	<RL
Indeno(1,2,3-c,d)pyrene	<RL	<RL
Dibenz(a,h)anthracene	<RL	<RL
Benzo(g,h,i)perylene	<RL	<RL

5.1.1.2 Total Organic Carbon in Sediment

The organic carbon content of sediments is measured and referred to as total organic carbon (TOC). TOC refers to the total amount of organic carbon in the sediment, and does not include mineralized carbon present as carbonates or bicarbonates. TOC concentrations ranged from 0.04 to1.60%(Table 5.1.2-1) among sampling locations. Organic carbon concentrations are proportional to biomass and may influence the rate of mercury biotransformation. TOC and methylmercury in sediment samples are shown to have a positive correlation where increased TOC concentrations are relative to methylmercury concentrations (FIG.5.1.2-2). Sediments with higher TOC concentrations had higher methylmercury concentrations.

Table 5.1.1-2. Sediment Analyses

Station Name	TOC (%)	Total Mercury (µg/g)dry	Methylmercury (ng/g)
Spillway	0.77	0.031	0.052
McCabe Cove (SF)	0.29	<0.011	0.039
Lower MF	1.60	0.017	0.403
Bidwell Arm	0.80	0.016	0.075
Lower SF Lk. Oroville	0.04	<0.011	<0.019
Upper MF Lk. Oroville	1.08	0.021	0.148
NF Arm Bloomer Canyon L. Oroville	0.60	<0.011	<0.019
S. Afterbay	0.12	<0.011	0.090
North Afterbay	0.14	<0.011	<0.019
NF Foreman	0.30	<0.011	0.029
N. Forebay Swim Area	0.27	0.016	0.097
Feather R US Afterbay Outlet	0.65	0.016	0.245
Mile Long Pond	0.10	<0.011	<0.019

5.1.2 Metal Contaminants

5.1.2.1 Mercury in Fish

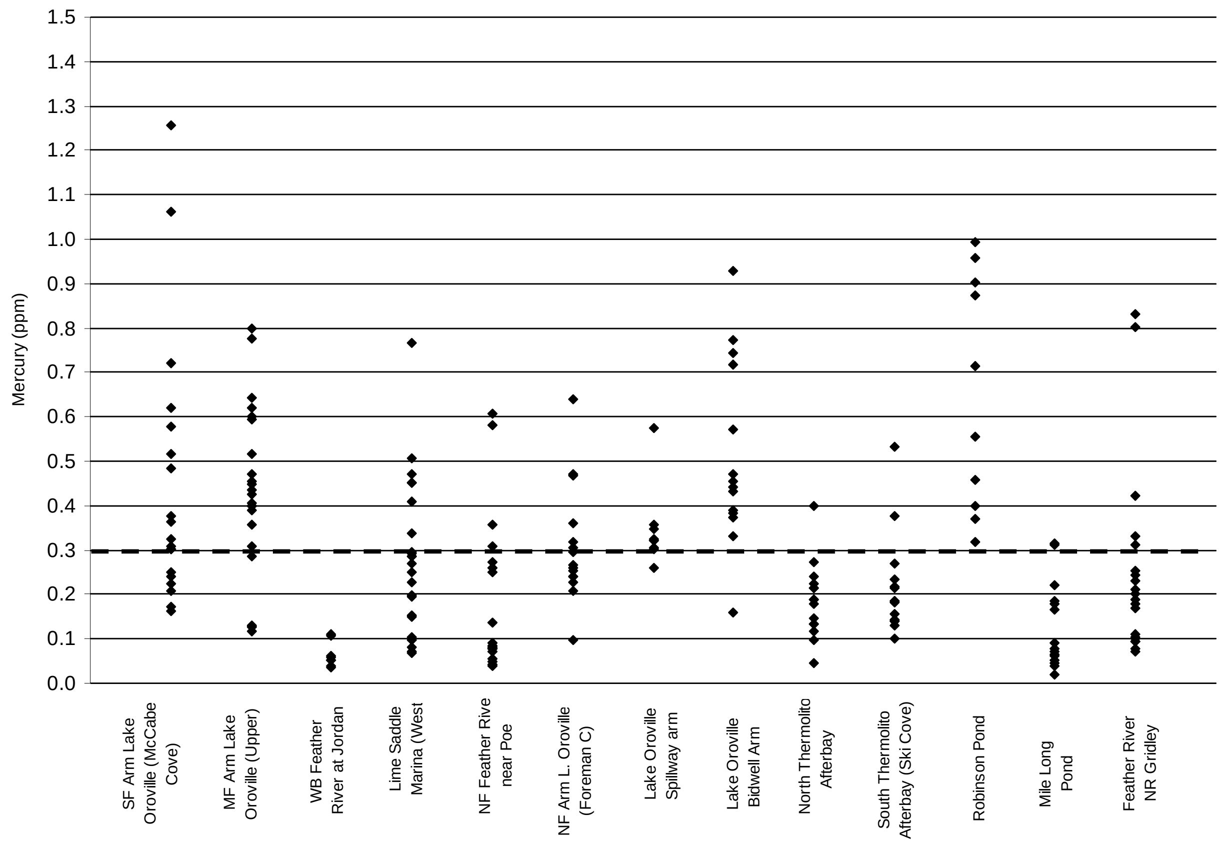
Mercury has no known beneficial biological function, and can be bioconcentrated in organisms and biomagnified though the food web (USFWS 1987). Mercury is a mutagen, teratogen, and carcinogen, and causes embryocidal, cytochemical, and histopathological effects. Earlier studies have indicated that total mercury concentrations in prey organisms for the protection of sensitive species of mammals and birds that regularly consume fish and other aquatic organisms should not exceed 0.1 mg/kg fresh weight for birds and 1.1 mg/kg for small mammals. Criteria for methylmercury in fish of 0.3 mg/kg have been developed for protection of human health (USEPA 2001). The USEPA, in consultation with the USFWS, concluded that this criterion should also be protective of federally listed aquatic and aquatic dependent wildlife species in California (USFWS 2003).

Concentrations of mercury in 214 individual fish sampled from the project area, tributaries, and the Oroville wildlife area ranged from 0.01 to 1.26 mg/kg with a mean of 0.3 mg/kg (Appendix A.). The USFWS recommendation for protection of avian wildlife from methylmercury ingested from prey (USFWS 2003) was exceeded in fish from all sampling sites. USFWS criterion for small mammals was exceeded at one station on the South Fork arm of Lake Oroville.

USEPA and OEHHA screening values were exceeded at all sampling locations for individual fish except rainbow trout species that were sampled from the West Branch Tributary just above Lake Oroville (FIG 5.1.2-1). Mercury concentrations were found to be elevated in Lake Oroville and Robinsons Pond. Most fish obtained from the Thermalito Afterbay and the Mile Long Pond were below USEPA screening values with the exception of several large mouth bass of large size. Fish obtained from the North Fork and West Branch Feather River had lower mercury concentrations comparatively to the Lake Oroville basin fish. Lower mercury concentrations in these fish may be partially attributed to the species of fish sampled at these tributary locations; only rainbow trout were sampled from the west branch and only one large rainbow trout, and one smaller sized brown trout were obtained from the North Fork. Due to insufficient quantity and size of tributary caught salmonids, comparisons between mercury biomagnification between Lake Oroville coho samples, and mercury levels that would be found in comparable-sized salmonids found upstream from the reservoir could not be determined. Top level predators such as larger bass, coho, and catfish had higher average mercury concentrations than fish at lower trophic levels including sunfish and smaller rainbow trout.

Most fish sampled from the Feather River near Gridley had mean mercury concentrations below USEPA screening values.   Some of the lower Feather River fish collected near Gridley contain concentrations of mercury that exceed guidelines.

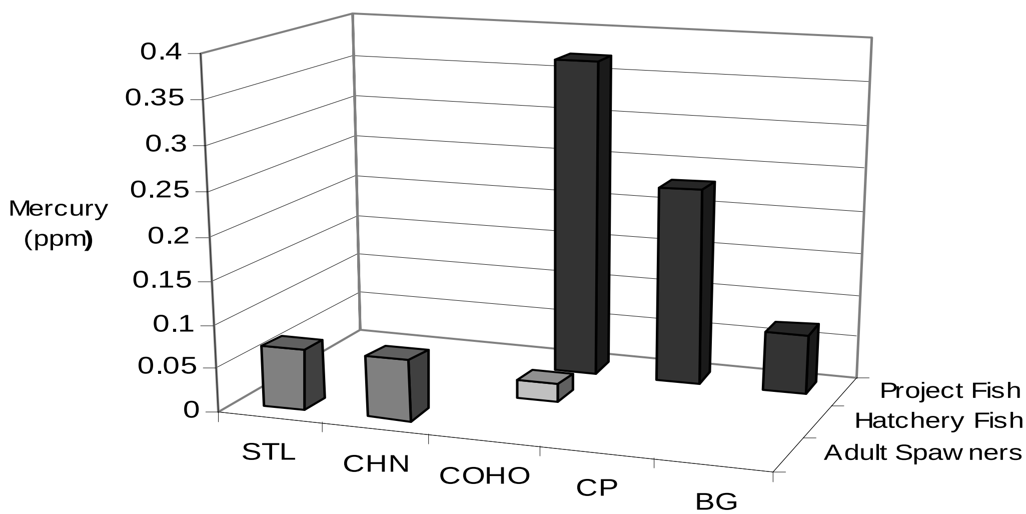
Figure 5.1.2-1. Mercury levels in individual fish samples



Individual fish tissue analysis from Phase 2 confirms the presence of mercury consistently exceeding EPA guidelines of 0.3 parts per million (ppm) in most fish species and locations sampled. Salmonids obtained from the Oroville Fish Hatchery were an exception where mercury in fish tissue composites were at relatively low concentrations (less than 0.1 ppm), which do not exceed any current criteria.

Adult, hatchery spawned steelhead and Chinook salmon composites were analyzed for total mercury to determine mercury levels found in adults returning to the hatchery. Hatchery-raised, juvenile coho were composited and analyzed along with adult coho composites that were obtained from Lake Oroville, in order to determine mercury levels in the coho prior to stocking in Lake Oroville. Mercury concentrations from hatchery raised coho composites are significantly lower than Lake Oroville coho composites, (FIG 5.1.2-2), indicating uptake of mercury in Lake Oroville coho. Hatchery and Lake Oroville coho composites have mean mercury concentrations of 0.02 and 0.37 mg/kg, respectively. These two populations are considered to be of the same lineage, however the coho in the hatchery were raised on hatchery feed and were less than 10 months old when sampled, while the lake coho were planted 1 to 2 years earlier and had time, as top-level piscivorous predators, to bioaccumulate mercury that was present in their forage. This demonstrates a direct link to the presence of mercury in the Lake Oroville food web. Mercury in returning adult steelhead and chinook composites were both 0.07 mg/kg, indicating that these fish do not bioaccumulate mercury in significant amounts during their life-history outside of the Project area. Carp and blue gill composites obtained from the Thermalito Afterbay were determined to have mean mercury concentrations of 0.23 and 0.07 mg/kg, respectively, and were found to be comparable to mercury levels found in carp and sunfish obtained from Lake Oroville. Carp occupy the herbivorous trophic level, while bluegill are seldom piscivorous and generally feed on small insects and zooplankton, resulting in lower mercury concentrations than were found in the higher trophic level bass and coho.

Figure 5.1.2-2. Mercury levels in composited fish samples

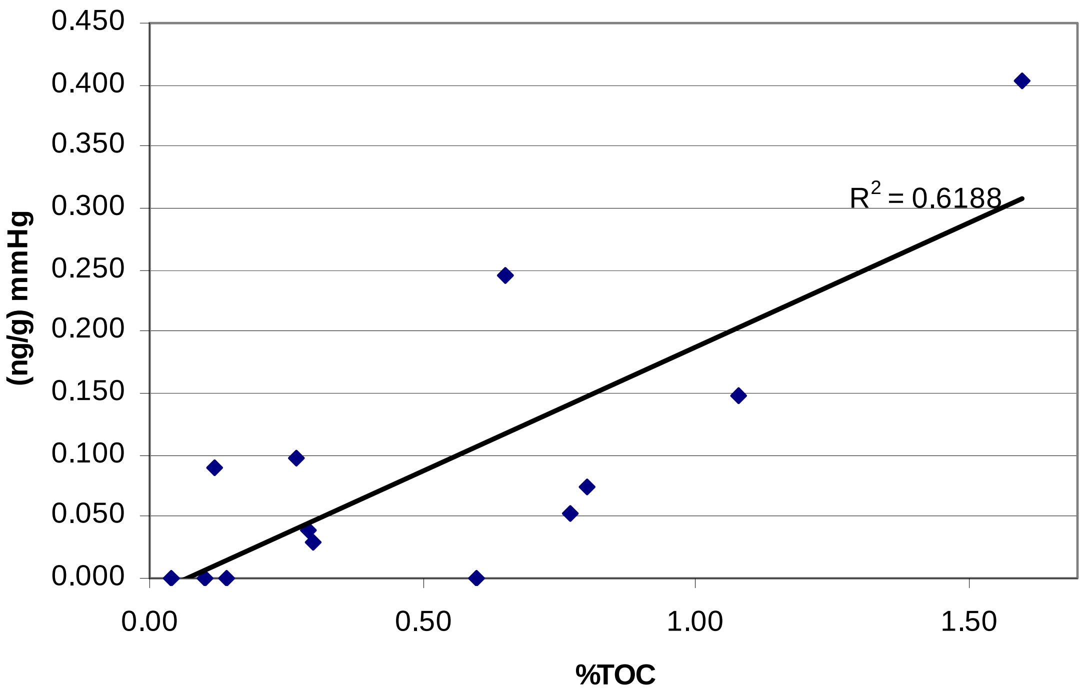


STL-Steelhead
CHN-Chinook
COHO- Coho Salmon
CP- Carp
BG- Blue Gill

5.1.2.2 Mercury in Sediment

Sediment is usually the primary source of mercury in most aquatic systems whereas the food web is the main pathway for accumulation. Sediments were collected during Phase 1 at 13 sampling locations, and contaminant analysis was conducted during Phase 2. Total mercury analysis at all locations were below laboratory reporting limits. Detectable levels of methylmercury were found widespread over the majority of sampling locations with a maximum concentration of 0.4 ng/g at the Middle Fork Arm of Lake Oroville (Table 5.1.1-2). Methylmercury is the biologically available form of mercury and has a positive correlation with total organic carbon (TOC) at sampled stations (FIG .5.1.2-3). Stations with elevated TOC have higher methylmercury concentrations, signifying greater biomass availability and possibly leading to increased rates of mercury biotransformation.

FIG. 5.1.2-3. Methylmercury and TOC Correlation (best fit linear R^2=0.6188)



6.0 ANALYSES

The purpose of Phase 2 is to determine the role of project waters in bioaccumulation by:

- Assessing contaminants in tributaries to the project,
- determining the distribution of contamination in project waters and extent of species affected, including other sport species (such as salmon, trout, and sunfish) and
- determining the extent of contamination in the river downstream from the project.

DWR collected fish during 2003 from several sites, including tributaries to Lake Oroville, Lake Oroville, Thermalito Forebay and Afterbay, Robinson and Mile Long ponds, Feather River near Gridley, and the main and annex hatchery facilities. Species collected include bass, minnows, sunfish, catfish, carp, salmonids, and suckers. Individual fish and composites were analyzed for mercury, while composites from the main and annex hatcheries were additionally analyzed for polynuclear aromatic hydrocarbons.

Sediments were collected during Phase 1 at 13 sampling locations within the project area, and contaminant analysis was conducted during Phase 2. Sediments were analyzed for total organic carbon, total mercury, and methylmercury.

Demonstration of compliance with basin plan objectives is necessary for the SWRCB to issue a water quality certification. Basin plan objectives include provisions against increases in suspended sediment discharges, deposition of material that adversely affect beneficial uses, and toxic substances that produce detrimental effects to humans, plants, animals, and aquatic life. Operation of the Oroville Project has decreased sediment discharges to the lower Feather River and is a benefit to meeting the aforementioned Basin Plan goals.

Fish collected from the West Branch and North Fork tributaries to Lake Oroville were of insufficient size and species composition to directly compare mercury levels with fish sampled from Lake Oroville. However, while mercury levels in tributary bass and trout were relatively low and did not exceed consumption level criteria, several of the larger Sacramento pikeminnow collected from the North Fork Feather River near the Poe Powerhouse exhibited mercury levels in excess of the EPA criteria, and could impact human and wildlife consumers of these fish.

While total mercury and methylmercury levels in project waters did not exceed any criteria, contamination in fish was identified. Mercury was reported in sport fish including spotted and large mouth bass, and channel catfish that exceed criteria to protect human health as well as wildlife. Though mercury levels in project area waters are low, biomagnification apparently has resulted in elevated mercury concentrations in fish from all project waters. Generally, fish tissue mercury levels were highest in the Middle Fork Arm of Lake Oroville with lower mercury levels detected in fish from the other arms of the lake. The North and South Fork Arms of Lake Oroville are fed by their respective forks of the Feather River, which have dams on them that trap most of the mercury contaminated sediment loads before they can be transported into the reservoir. The Middle Fork Feather River upstream from Lake Oroville has no such dams, and thus, allows unimpeded transport of mercury contaminated sediment loads to the Middle Fork Arm of Lake Oroville. Analysis of mercury levels in Age-0 coho composites, collected from the hatchery prior to introduction to Lake Oroville, when compared with mercury levels found in Age-1 to 2 coho composites collected from Lake Oroville, indicate mercury bioaccumulation is taking place as these fish grow to catchable size in the lake. Tissue analysis of returning adult Chinook salmon and steelhead indicate that these fish do not bioaccumulate mercury during their life history outside of the Project area, to the same extent as representative salmonids (coho) in Lake Oroville do.

While mercury was detected in some of the lower Feather River fish at levels exceeding criteria, the levels appear to be, on average, lower than what occurs in certain areas of Lake Oroville.

Some polynuclear aromatic hydrocarbons (PAH) were detected in fish tissue composites obtained from the Oroville Fish Hatchery. Hatchery composite PAHs with associated EPA screening value criteria, including benzo(a)pyrene, were below reporting limits. However, the DFG Laboratory reporting limits were over three times higher than the screening value for benzo(a)pyrene. Therefore no clear conclusions can be drawn for benzo(a)pyrene

While sediment analyses yielded total mercury levels that were below laboratory detection limits, methylmercury was found over the majority of sampling locations, with the highest concentration at the Middle Fork Arm of Lake Oroville. Methylmercury has a positive correlation with sediment total organic carbon (TOC) levels at sampled stations. Stations with elevated TOC have higher methylmercury concentrations, signifying greater biomass availability and possibly leading to increased rates of mercury biotransformation.

Massive amounts of mercury were brought into the northern Sierra Nevada during the gold mining era. Large quantities of mercury still exist today in the Oroville lakebed, tributaries, and surrounding lands. Methylation of mercury would be occurring regardless of whether the Oroville Project was in existence, however, the methylation process may have increased where Lake Oroville now resides due to the reservoir environment. Mercury levels downstream from the Project have likely been reduced due to sediment trapping behind Oroville Dam. This situation is very common among many California reservoirs impacted by historic gold mining activities, especially west slope Sierra reservoirs. Very little can be done to reduce the mercury problem, short of identifying and remediating a large but unknown number of abandoned mine sites contributing mercury to area waters, as well as removing an enormous amount of mercury contaminated sediments already present in the lakebed.

DWR can employ best management practices to reduce sedimentation from its activities. DWR will provide this information to the appropriate agencies for a determination on possible issuance of public health warnings.

7.0 REFERENCES

Brodberg, R.K. and G.A. Pollock. 1999. Prevalence of Selected Target Chemical Contaminants in Sport Fish from Two California Lakes: Public Health Designed Screening Study. California Office of Environmental Health Hazard Assessment. Sacramento, California.

Bureau of Reclamation. 1993. Memorandum to National Irrigation Water Quality Program Manager regarding Predicted Selenium Effect Levels for Kendrick and Middle Green River Remediation (Irrigation Drainage). 4 p.

CVRWQCB 2003. A Compilation of Water Quality Goals. Central Valley Regional Water Quality Control Board. Sacramento, California.

NAS 1972. Water Quality Criteria 1972; a Report of the Committee on Water Quality Criteria. National Academy of Sciences and National Academy of Engineering. U.S. Environmental Protection Agency. EPA R3-73-033.

Newell, A.J., D.W. Johnson, and L.K. Allen 1987. Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife. Department of Environmental Conservation. New York.

SFEI 1996. Mercury Effects, Sources, and Control Measures. San Francisco Estuary Institute. Oakland, California.

SWRCB 1996. Toxic Substances Monitoring Program, 1994-95 Data Report. California State Water Resources Control Board. Sacramento, California.

USEPA 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1. Fish Sampling and Analysis., 3rd Ed. EPA-823-B-00-007. U.S. Environmental Protection Agency. Washington, D.C.

USEPA 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. EPA-823-R-01-001. U.S. Environmental Protection Agency. Washington, D.C.

USFWS 1986a. Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85 (1.7). U.S. Fish and Wildlife Service. Laurel, Maryland.

USFWS 1987. Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85 (1.10). U.S. Fish and Wildlife Service. Laurel, Maryland.

USFWS 2003. Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California. U.S. Fish and Wildlife Service. Sacramento, California.

USGS 1994. Guidelines for Collecting and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants for the National Water Quality Assessment Program. U. S. Geological Survey Open File Report 94-458.

8.0 APPENDICES

Appendix A. Raw Data for total mercury in fish fillets collected and analyzed during Phase 2.

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
Lake Oroville Bidwell Arm	4000	382	367	385	LMB	78.9	0.93	4.40
Lake Oroville Bidwell Arm	4001	383	365	368	LMB	77.8	0.37	1.69
Lake Oroville Bidwell Arm	4002	408	395	412	LMB	81.0	0.77	4.06
Lake Oroville Bidwell Arm	4003	390	381	410	SPB	77.9	0.57	2.59
Lake Oroville Bidwell Arm	4005	360	355	382	SPB	76.3	0.43	1.82
Lake Oroville Bidwell Arm	4006	337	333	358	SPB	76.3	0.47	2.00
Lake Oroville Bidwell Arm	4007	346	342	365	SPB	76.5	0.45	1.94
Lake Oroville Bidwell Arm	4009	360	357	386	SPB	78.3	0.39	1.80
Lake Oroville Bidwell Arm	4013	310	295	318	COHO	74.6	0.16	0.63
Lake Oroville Bidwell Arm	4015	425	412	428	LMB	78.1	0.38	1.75
Lake Oroville Bidwell Arm	4016	402	394	420	SPB	77.4	0.72	3.18
Lake Oroville Bidwell Arm	4018	330	311	328	LMB	78.1	0.33	1.51
Lake Oroville Bidwell Arm	4019	352	335	354	LMB	76.9	0.44	1.91
Lake Oroville Bidwell Arm	4020	366	350	367	LMB	80.3	0.74	3.77
NF Arm L. Oroville (Bloomer Cnyn)	4027	370	360	382	SPB	76.8	0.47	2.01
NF Arm L. Oroville (Bloomer Cnyn)	4028	348	333	348	SPB	77.1	0.27	1.16
NF Arm L. Oroville (Bloomer Cnyn)	4029	338	333	351	SPB	76.6	0.30	1.27
NF Arm L. Oroville (Bloomer Cnyn)	4031	325	316	331	SPB	77.7	0.24	1.09
NF Arm L. Oroville (Bloomer Cnyn)	4033	308	303	318	SPB	77.0	0.23	0.98
NF Arm L. Oroville (Bloomer Cnyn)	4034	290	282	306	SPB	76.7	0.31	1.31
NF Arm L. Oroville (Bloomer Cnyn)	4036	375	349	396	SPB	77.1	0.36	1.58
NF Arm L. Oroville (Bloomer Cnyn)	4037	366	362	385	SPB	77.8	0.47	2.10
NF Arm L. Oroville (Bloomer Cnyn)	4040	295	280	297	SPB	77.3	0.26	1.15
NF Arm L. Oroville (Bloomer Cnyn)	4041	295	284	299	SPB	77.0	0.24	1.04
Upper MF Lake Oroville	4081	387	374	396	SPB	75.9	0.59	2.47
Upper MF Lake Oroville	4082	375	363	385	SPB	77.5	0.64	2.85

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
Upper MF Lake Oroville	4083	373	363	383	SPB	76.0	0.80	3.32
Upper MF Lake Oroville	4084	360	350	370	SPB	76.1	0.44	1.82
Upper MF Lake Oroville	4086	350	330	351	SPB	77.4	0.78	3.45
Upper MF Lake Oroville	4088	340	335	353	SPB	77.4	0.62	2.74
Upper MF Lake Oroville	4091	257	245	256	SPB	77.3	0.41	1.79
Upper MF Lake Oroville	4092	261	248	265	SPB	77.4	0.40	1.76
Upper MF Lake Oroville	4093	285	268	287	SPB	76.8	0.47	2.02
Upper MF Lake Oroville	4094	261	250	264	SPB	76.9	0.45	1.96
Upper MF Lake Oroville	4095	258	248	261	SPB	77.4	0.31	1.37
Upper MF Lake Oroville	4096	253	245	261	SPB	76.6	0.52	2.20
Upper MF Lake Oroville	4097	261	230	240	SPB	77.7	0.45	2.01
Upper MF Lake Oroville	4098	252	254	270	SPB	76.3	0.39	1.65
Upper MF Lake Oroville	4099	228	244	257	SPB	77.4	0.36	1.58
Upper MF Lake Oroville	4100	241	221	231	SPB	78.4	0.29	1.32
Upper MF Lake Oroville	4103	540	525	580	CHC	75.7	0.40	1.65
Upper MF Lake Oroville	4104	502	465	515	CHC	76.8	0.60	2.60
Lime Saddle Marina	4110	455	434	456	LMB	78.8	0.45	2.12
Lime Saddle Marina	4111	380	369	387	LMB	79.3	0.47	2.27
Lime Saddle Marina	4112	424	407	430	LMB	79.1	0.51	2.43
Lime Saddle Marina	4115	348	337	350	LMB	79.3	0.41	1.98
Lime Saddle Marina	4116	383	306	384	LMB	79.5	0.77	3.72
Lime Saddle Marina	4117	350	341	365	SPB	78.0	0.45	2.05
Lime Saddle Marina	4118	328	316	341	SPB	78.2	0.29	1.35
Lime Saddle Marina	4119	312	304	321	SPB	78.0	0.29	1.30
Lime Saddle Marina	4123	321	311	331	SPB	78.2	0.34	1.54
Lime Saddle Marina	4124	290	282	300	SPB	77.1	0.30	1.29

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
Lime Saddle Marina	4126	285	278	296	SPB	77.7	0.29	1.28
Lime Saddle Marina	4127	249	240	255	SPB	77.3	0.23	1.00
Lime Saddle Marina	4133	270	264	278	SPB	78.7	0.27	1.26
Lime Saddle Marina	4136	205	197	206	SPB	78.4	0.25	1.14
Lime Saddle Marina	4137	170	172	180	BGS	79.7	0.10	0.47
Lime Saddle Marina	4138	110	100	108	BGS	78.4	0.10	0.47
Lime Saddle Marina	4139	102	105	112	BGS	79.7	0.07	0.36
Lime Saddle Marina	4140	143	138	145	GSF	80.4	0.07	0.36
Lime Saddle Marina	4141	484	455	505	CP	78.5	0.15	0.71
Lime Saddle Marina	4142	550	530	593	CP	80.2	0.20	0.99
Lime Saddle Marina	4143	575	538	598	CP	79.3	0.15	0.72
Lime Saddle Marina	4145	498	486	537	CP	76.4	0.20	0.84
Lime Saddle Marina	4146	308	302	323	COHO	76.3	0.08	0.34
NF Arm L. Oroville (Bloomer Cnyn)	4198	350	340	360	COHO	77.0	0.64	2.77
NF Arm L. Oroville (Bloomer Cnyn)	4199	327	315	355	COHO	77.5	0.10	0.44
North Thermolito Afterbay	4210	485	466	525	CP	76.5	0.18	0.78
North Thermolito Afterbay	4211	548	530	580	CP	74.1	0.21	0.83
North Thermolito Afterbay	4212	534	516	575	CP	78.6	0.10	0.45
North Thermolito Afterbay	4213	538	523	588	CP	74.9	0.19	0.75
North Thermolito Afterbay	4214	518	506	553	CP	77.6	0.12	0.52
North Thermolito Afterbay	4215	408	405	415	LMB	78.6	0.40	1.87
North Thermolito Afterbay	4216	324	320	330	LMB	79.2	0.27	1.31
North Thermolito Afterbay	4217	277	278	290	LMB	78.3	0.14	0.67
North Thermolito Afterbay	4218	292	296	305	LMB	78.3	0.19	0.88
North Thermolito Afterbay	4219	328	328	340	LMB	78.4	0.22	1.03
North Thermolito Afterbay	4222	225	226	240	LMB	77.8	0.13	0.60

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
North Thermolito Afterbay	4223	365	366	378	LMB	78.3	0.21	0.98
North Thermolito Afterbay	4225	320	319	332	LMB	79.8	0.24	1.18
North Thermolito Afterbay	4227	243	240	256	LMB	77.9	0.13	0.59
North Thermolito Afterbay	4230	198	194	203	RES	77.9	0.05	0.20
North Thermolito Afterbay	4232	174	167	178	RES	78.4	0.03	0.14
Robinson Pond	4235	648	638	689	CP	65.6	0.46	1.33
Robinson Pond	4236	632	610	656	CP	65.1	0.32	0.91
Robinson Pond	4242	421	405	420	LMB	78.3	0.71	3.30
Robinson Pond	4243	416	406	420	LMB	70.8	1.00	3.41
Robinson Pond	4244	416	407	427	LMB	77.2	0.90	3.95
Robinson Pond	4245	390	385	404	LMB	77.7	0.96	4.30
Robinson Pond	4247	382	369	386	LMB	77.6	0.87	3.89
Robinson Pond	4250	402	386	408	LMB	78.9	0.37	1.75
Robinson Pond	4251	369	360	373	LMB	78.7	0.55	2.60
Robinson Pond	4254	262	242	260	LMB	78.6	0.40	1.86
South Thermolito Afterbay (Ski Cove)	4269	439	420	438	LMB	77.8	0.53	2.39
South Thermolito Afterbay (Ski Cove)	4270	433	423	438	LMB	79.1	0.38	1.80
South Thermolito Afterbay (Ski Cove)	4271	418	418	434	LMB	79.0	0.19	0.89
South Thermolito Afterbay (Ski Cove)	4272	369	358	370	LMB	77.8	0.27	1.22
South Thermolito Afterbay (Ski Cove)	4273	341	335	348	LMB	77.4	0.21	0.95
South Thermolito Afterbay (Ski Cove)	4274	382	373	390	LMB	78.7	0.22	1.03
South Thermolito Afterbay (Ski Cove)	4275	407	390	411	LMB	79.6	0.18	0.89
South Thermolito Afterbay (Ski Cove)	4277*	355	345	357	LMB	77.5	0.19	0.83
South Thermolito Afterbay (Ski Cove)	4278*	332	325	339	LMB	77.3	0.23	1.03
South Thermolito Afterbay (Ski Cove)	4279	218	205	218	LMB	76.8	0.13	0.56
South Thermolito Afterbay (Ski Cove)	4281	184	185	192	LMB	79.9	0.14	0.69

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
South Thermolito Afterbay (Ski Cove)	4283	174	175	183	LMB	78.7	0.14	0.66
South Thermolito Afterbay (Ski Cove)	4284	206	205	214	LMB	78.1	0.16	0.72
South Thermolito Afterbay (Ski Cove)	4286	165	162	170	LMB	79.2	0.14	0.67
South Thermolito Afterbay (Ski Cove)	4288	153	152	158	LMB	80.0	0.10	0.51
SF Arm Lake Oroville (McCabe Cove)	4294	389	373	395	LMB	78.9	0.72	3.41
SF Arm Lake Oroville (McCabe Cove)	4295	393	385	394	LMB	79.2	1.06	5.11
SF Arm Lake Oroville (McCabe Cove)	4296	363	354	380	LMB	79.1	1.26	6.03
SF Arm Lake Oroville (McCabe Cove)	4300	326	315	330	LMB	79.5	0.58	2.83
SF Arm Lake Oroville (McCabe Cove)	4301	305	295	309	LMB	78.7	0.52	2.42
SF Arm Lake Oroville (McCabe Cove)	4302	298	290	304	LMB	78.1	0.48	2.21
SF Arm Lake Oroville (McCabe Cove)	4305	209	206	221	SPB	77.4	0.22	0.99
SF Arm Lake Oroville (McCabe Cove)	4306	218	216	231	SPB	78.8	0.33	1.53
SF Arm Lake Oroville (McCabe Cove)	4309	235	233	248	SPB	77.6	0.30	1.35
SF Arm Lake Oroville (McCabe Cove)	4310	187	190	198	SPB	78.6	0.36	1.70
SF Arm Lake Oroville (McCabe Cove)	4311	254	247	266	SPB	77.3	0.30	1.33
SF Arm Lake Oroville (McCabe Cove)	4312	280	275	290	SPB	77.4	0.17	0.76
SF Arm Lake Oroville (McCabe Cove)	4313	258	255	263	BCR	80.1	0.25	1.26
SF Arm Lake Oroville (McCabe Cove)	4314	240	245	248	BCR	79.4	0.24	1.17
Upper MF Lake Oroville	4323	438	428	467	CHC	77.3	0.43	1.88
Upper MF Lake Oroville	4324	160	147	160	BG	79.7	0.13	0.62
Upper MF Lake Oroville	4325	167	151	164	BG	79.1	0.12	0.57
Upper MF Lake Oroville	4326	140	135	144	BG	78.9	0.13	0.60
Upper MF Lake Oroville	4328	135	128	138	BG	78.8	0.13	0.61
Upper MF Lake Oroville	4330	132	125	132	BG	79.1	0.13	0.62
Upper MF Lake Oroville	4333	127	120	129	BG	79.7	0.09	0.46
Upper MF Lake Oroville	4338	129	126	138	BG	79.5	0.13	0.61

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
Upper MF Lake Oroville	4341	125	119	126	BG	79.5	0.10	0.51
Upper MF Lake Oroville	4343	123	117	124	BG	79.4	0.14	0.67
Upper MF Lake Oroville	4344	120	114	120	BG	78.9	0.09	0.45
SF Arm Lake Oroville (McCabe Cove)	4346	362	350	389	CHC	78.4	0.21	0.97
SF Arm Lake Oroville (McCabe Cove)	4347	512	501	544	CHC	78.8	0.62	2.93
SF Arm Lake Oroville (McCabe Cove)	4348	405	395	434	CHC	77.9	0.31	1.40
SF Arm Lake Oroville (McCabe Cove)	4349	410	394	446	CHC	76.8	0.38	1.65
SF Arm Lake Oroville (McCabe Cove)	4350	395	384	425	CHC	76.4	0.16	0.69
NF Arm L. Oroville (Bloomer Cnyn)	4352	520	503	556	CHC	71.1	0.25	0.88
NF Arm L. Oroville (Bloomer Cnyn)	4353	407	395	445	CHC	75.1	0.32	1.27
NF Arm L. Oroville (Bloomer Cnyn)	4354	377	368	420	CHC	74.7	0.21	0.82
Mile Long Pond	4357	296	291	304	LMB	80.2	0.31	1.58
Mile Long Pond	4358	326	212	335	LMB	78.5	0.19	0.87
Mile Long Pond	4359	360	359	374	LMB	77.9	0.31	1.41
Mile Long Pond	4360	329	326	343	LMB	79.5	0.22	1.07
Mile Long Pond	4361	289	286	299	LMB	78.6	0.18	0.86
Mile Long Pond	4363	273	270	failed to record	BRB	79.6	0.04	0.19
Mile Long Pond	5000	135	130	141	Hy	79.2	0.05	0.22
Mile Long Pond	5007	126	121	131	Hy	79.9	0.06	0.32
Mile Long Pond	5008	155	158	163	Hy	80.4	0.06	0.31
Mile Long Pond	5015	131	126	138	Hy	81.5	0.08	0.43
Mile Long Pond	5018	161	156	166	Hy	81.2	0.07	0.38
Mile Long Pond	5019	134	125	136	Hy	78.9	0.05	0.25
Mile Long Pond	5021	175	175	188	Hy	83.2	0.17	0.99
Mile Long Pond	5022	130	114	132	Hy	79.2	0.02	0.10
Mile Long Pond	5023	172	165	176	Hy	87.2	0.09	0.73

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
Mile Long Pond	5024	151	146	158	Hy	78.8	0.06	0.27
South Thermolito Afterbay (Ski Cove)	5034	127	119	128	RES	79.6	0.09	0.46
Lake Oroville NR Intake Structure	5048	409	394	420	COHO	72.5	0.57	2.09
Lake Oroville NR Intake Structure	5049	470	**410	440	COHO	73.6	0.32	1.22
Lake Oroville NR Intake Structure	5050	445	432	456	COHO	73.1	0.26	0.97
Lake Oroville NR Intake Structure	5051	430	**457	478	COHO	70.2	0.32	1.09
Lake Oroville NR Intake Structure	5052	458	446	478	COHO	73.0	0.30	1.12
Lake Oroville NR Intake Structure	5053	420	414	436	COHO	71.5	0.36	1.25
Lake Oroville NR Intake Structure	5054	396	385	410	COHO	74.9	0.35	1.39
Lake Oroville NR Intake Structure	5055	432	426	450	COHO	73.7	0.31	1.17
Lake Oroville NR Intake Structure	5056	434	423	454	COHO	73.0	0.32	1.19
NF Feather R NR Poe PH	6029	362	350	374	SPB	78.1	0.31	1.40
NF Feather R NR Poe PH	6030	242	233	246	SMB	76.4	0.09	0.36
NF Feather R NR Poe PH	6031	282	274	290	SMB	76.7	0.25	1.07
NF Feather R NR Poe PH	6033	464	440	480	PM	78.2	0.58	2.67
NF Feather R NR Poe PH	6035	222	210	222	SMB	77.8	0.08	0.35
NF Feather R NR Poe PH	6036	138	135	143	SMB	76.7	0.04	0.17
NF Feather R NR Poe PH	6037	203	197	208	SMB	77.5	0.08	0.36
NF Feather R NR Poe PH	6039	161	156	164	SMB	76.7	0.04	0.19
NF Feather R NR Poe PH	6041	314	310	336	PM	78.7	0.08	0.36
NF Feather R NR Poe PH	6042	216	211	221	BT	75.9	0.09	0.38
NF Feather R NR Poe PH	6043	256	252	265	SMB	77.0	0.14	0.60
NF Feather R NR Poe PH	6044	368	360	380	RBT	75.8	0.07	0.29
NF Feather R NR Poe PH	6045	270	264	275	SMB	78.3	0.27	1.25
NF Feather R NR Poe PH	6046	345	327	370	SMB	76.2	0.36	1.49
NF Feather R NR Poe PH	6047	415	400	430	PM	78.2	0.61	2.78

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
NF Feather R NR Poe PH	6049	375	358	384	PM	79.5	0.26	1.27
NF Feather R NR Poe PH	6050	237	235	253	HH	77.9	0.05	0.22
WB Feather R At JHR	6052	247	239	253	RBT	76.7	0.04	0.16
WB Feather R At JHR	6054	194	186	200	RBT	76.7	0.03	0.15
WB Feather R At JHR	6070	212	203	216	RBT	77.8	0.06	0.28
WB Feather R At JHR	6071	222	216	231	RBT	75.0	0.11	0.43
WB Feather R At JHR	6072	200	192	206	RBT	77.0	0.05	0.22
WB Feather R At JHR	6073	236	230	243	RBT	74.9	0.11	0.44
WB Feather R At JHR	6075	188	178	191	RBT	75.5	0.06	0.24
WB Feather R At JHR	6077	167	158	169	RBT	75.0	0.05	0.20
Feather R NR Gridley	6078	444	428	505	HH	76.5	0.83	3.54
Feather R NR Gridley	6079	273	270	296	HH	77.3	0.09	0.41
Feather R NR Gridley	6080	337	332	360	HH	76.6	0.11	0.47
Feather R NR Gridley	6081	226	222	243	HH	78.0	0.08	0.35
Feather R NR Gridley	6082	269	265	290	HH	78.8	0.09	0.44
Feather R NR Gridley	6083	230	223	240	HH	78.8	0.07	0.31
Feather R NR Gridley	6084	337	329	353	HH	78.5	0.18	0.83
Feather R NR Gridley	6085	321	315	337	PM	77.3	0.21	0.93
Feather R NR Gridley	6086	307	303	323	PM	77.1	0.23	1.01
Feather R NR Gridley	6087	317	310	333	PM	77.8	0.20	0.91
Feather R NR Gridley	6088	272	264	289	PM	82.9	0.33	1.93
Feather R NR Gridley	6089	324	315	338	PM	75.7	0.24	0.99
Feather R NR Gridley	6090	235	228	244	PM	78.2	0.10	0.47
Feather R NR Gridley	6091	236	232	247	PM	78.0	0.10	0.46
Feather R NR Gridley	9000	255	252	264	LMB	78.7	0.17	0.81
Feather R NR Gridley	9001	283	280	291	LMB	79.9	0.28	1.39

Station Name	Sample Identification	Fork Length	Re-measured Fork Length (mm)	Re-measured Total Length (mm)	Spec. Code	Percent Moisture	Hg, wet weight concentration, µg/g	Hg, dry weight concentration, µg/g
Feather R NR Gridley	9003	302	295	308	LMB	79.4	0.19	0.91
Feather R NR Gridley	9004	460	450	470	LMB	80.3	0.80	4.06
Feather R NR Gridley	9005	323	318	331	LMB	78.7	0.25	1.19
Feather R NR Gridley	9006	398	386	404	LMB	80.0	0.42	2.11
South Thermolito Afterbay (Ski Cove)	COMP A				BG	79.0	0.09	0.43
North Thermolito Afterbay	COMP D				BG	77.9	0.05	0.24
South Thermolito Afterbay (Ski Cove)	COMP E				CP	73.0	0.13	0.47
Mile Long Pond	COMP F				CP	77.4	0.32	1.41
Lake Oroville NR Intake Structure	COMP Q				COHO	72.8	0.33	1.19
Lake Oroville NR Intake Structure	COMP R				COHO	72.3	0.34	1.25
Lake Oroville NR Intake Structure	COMP S				COHO	72.9	0.44	1.62
Reporting Limit							0.01	0.03

SPB-Spotted Bass, LMB-Largemouth Bass, SMB-Smallmouth Bass, CHC-Channel Catfish, BRB-Brown Bullhead, RES-Redear Sunfish, PM-Pike Minnow, HH-Hardhead, RBT-Rainbow Trout, BT-Brown Trout, COHO-Coho Salmon, BG-Blue Gill, BGS-Blue Gill Sunfish, HY- Sunfish Hybrid, BCR-Black Crappie, SASU-Sacramento Sucker, CHN- Chinook Salmon, STH- Steelhead